MOVEMENT OF THE STORM OF SEPTEMBER 25–30, 1951

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INTRODUCTION

In the day to day practice of preparing forecasts and analyses, meteorologists, working under the pressure of tight schedules and deadlines, are usually forced to look upon the changing features of the weather charts in a comparatively hurried manner. Frequently, meteorologists resort to standardized, or idealized, concepts often referred to as models. One such model of the core of a Low pictures the axis, in the early stages, as oriented toward the northwest with flat slope from the surface position to higher levels; as the storm deepens and occludes, the axis is expected to become more and more nearly vertical as the core at upper levels gradually overtakes the surface position. Individual storms vary from the model and a knowledge of these variations leads to a better understanding of the usefulness of such a device. The following presentation, limited as it is to one case, the storm of September 25–30, 1951, is not intended to do more than examine the orientation and motion of the axis of a particular storm which became well developed and occluded.

The storm developed from a small frontal wave with a central pressure of 1,000 mb. which was located over extreme southwestern South Dakota on September 25, 1951, at 1830 GMT (fig. 1). The wave began to occlude by the end of the first day and during the following 24 hours deepened considerably. On September 27 (fig. 2) it was southwest of the tip of James Bay, Canada, with a central pressure of 982 mb. On the 30th, the center was located in the vicinity of 60° N. Lat. and 50° W. Long., practically unchanged in strength (987 mb). Thus the storm moved from South Dakota to the ocean, east of Labrador, in just over 5 days. Its direction of motion was almost constantly toward the northeast and at a nearly uniform rate of movement (19 m. p. h.). These facts plus strong deepening provoked the speculation as to whether the motion of this storm could have been successfully forecast. This will be discussed in the last section of this article after the behavior of the core has been examined.

THE BEHAVIOR OF THE CORE

To determine the variations of the core from the simple model which has been depicted, the successive positions of the surface, 700-mb., and 500-mb. centers were plotted in figure 3. On the work sheet for this figure are details which could not be included in the final illustration because of the confusion of lines. However, the information is embodied in table 1. The numbers used in expressing distances were arrived at by measuring the distance between the surface center of the Low and the point on the ground directly beneath the specified upper-level low center.

During the 25th, the new wave developed and moved eastward and northeastward across South Dakota (fig. 3).

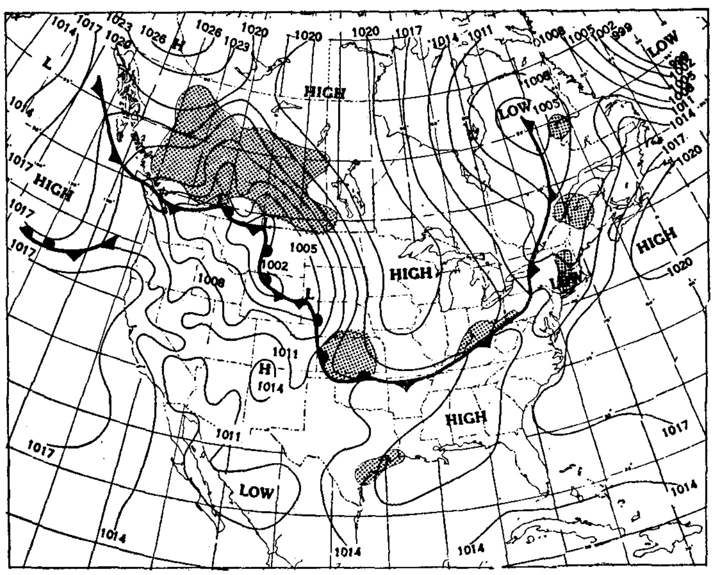

FIGURE 1.—Surface weather chart, 1830 GMT, September 25, 1951. Shading indicates areas of active precipitation.

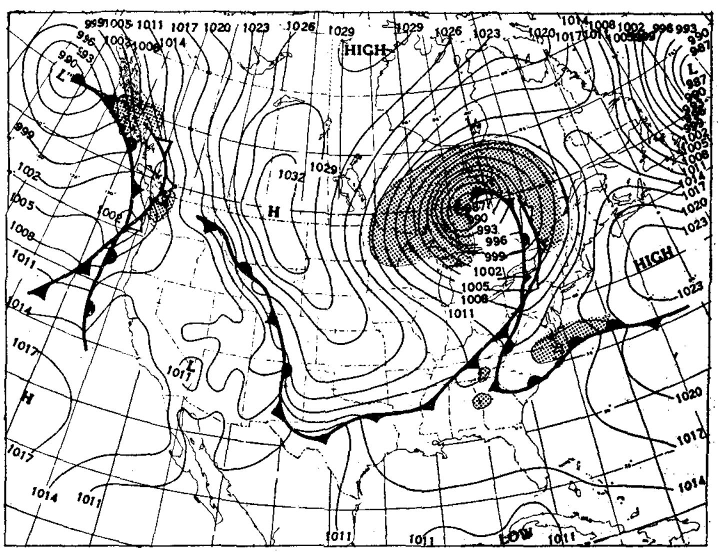

FIGURE 2.—Surface weather chart, 1830 GMT, September 27, 1951.

TABLE 1.—*Horizontal distance and orientation between various segments of the storm core (through the interval from surface to 500 mb.)*

	Time (GMT)	Surface to 700 mb.		700 mb. to 500 mb.		Surface to 500 mb.	
		Orientation	Distance (miles)	Orientation	Distance (miles)	Orientation	Distance (miles)
Sept. 26	03	NNW	630				
	15	NW	450	NW	300	NW	750
27	03	WNW	220	WNW	210	WNW	430
	15	W	100	SW	50	WSW	150
28	03	SW	90	SW	130	SW	200
	15	None	0	NW	100	NW	100
29	03	None	0	WNW	110	WNW	110
	15	SW	30	WNW	130	W	150
30	03	W	80	W	100	W	180
	15	WSW	127	SW	90	SW	195

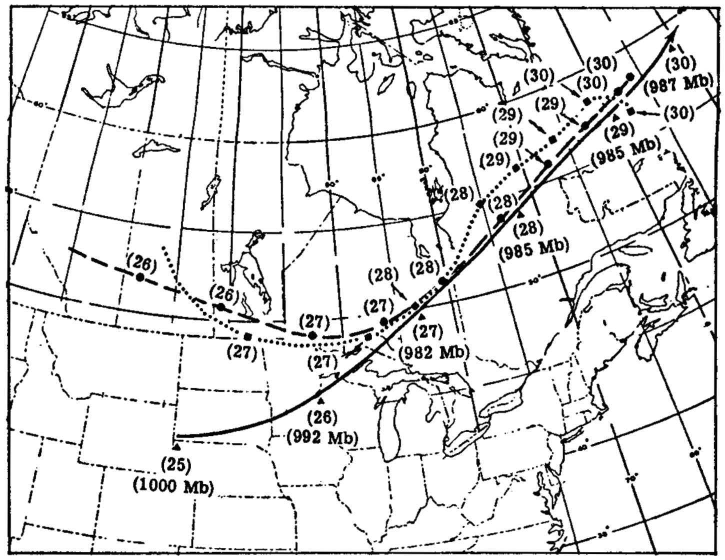

FIGURE 3.—Tracks of storm at various levels. Solid line=path of surface center; dashed line=path of 700-mb. center; dotted line=path of 500-mb. center; triangles=surface position and central pressure at 1830 GMT each date; dots and blocks=positions of centers at 700 and 500 mb., respectively, at 0300 and 1500 GMT each date.

On this first day, the core of the storm could not be reliably identified above 700 mb.; however, it appeared to be inclined northwestward from the surface to 500 mb. At 0300 GMT (26th) the 700-mb. center was about 630 miles north-northwest of the surface low, and 12 hours later the orientation was about the same, but the distance had decreased to 450 miles (refer to table 1). At this time (1500 GMT, 26th) the surface Low was located to the southwest of St. Cloud, Minn., with a suggestion of a center at 500 mb. in the vicinity of Prince Albert, Saskatchewan, Canada. So far, observations seem to be in agreement with usual ideas on the subject. As the Low developed the core moved toward a more vertical position. At the end of the next 12 hours (0300 GMT, 27th) the surface Low was over Houghton, Mich., with its 700-mb. counterpart 220 miles to the west-northwest. With respect to the surface center, the 500-mb. low was 430 miles to the west-northwest.

By 1500 GMT of this same day the slope had steepened considerably with only 150 miles between the surface center and the 500-mb. Low center to the west-southwest. A large contribution to this steepening came from the 700- to 500-mb. segment where the distance decreased from 210 to 50 miles in the 12 hours ending 1500 GMT (27th). Measurements of the 12-hour movement of the center at various levels gave 40 m. p. h. for the 500-mb. center, 21 m. p. h. for the 700-mb. Low and 18 m. p. h. for the surface center. Reference to figure 3 will make obvious the motion of the core at this time as the surface Low moved northeastward, the 700-mb. center moved east-northeastward and the 500-mb. Low moved straight eastward. The result was the core swung counterclockwise in "behind" the surface Low and moved more rapidly at higher elevations.

In the next 24 hours (1500 GMT, 27–28th) the core underwent some interesting changes. For the first half of this period the core was orientated southwest from the surface to 500 mb. with a somewhat flatter slope. The surface to 700-mb. slope had become nearly vertical (90 miles) but the 700-mb. to 500-mb. distance had increased from 50 to 130 miles. The vertical gradient of horizontal speed changed during the 12 hours ending at 0300 GMT on the 28th as the 500-mb. center moved at 16 m. p. h. and the 700-mb. and the surface centers moved at 23 m. p. h. At the end of the next 12 hours (1500 GMT, 28th), the core was vertical up to 700 mb. and not far from vertical (100 miles) from the 700- to 500-mb. levels, but two changes had taken place: the core was now orientated northwest, as on the 26th, from 700- to 500-mb. with the surface Low moving at 18 m. p. h., the 700-mb. center moving at 25 m. p. h. and the 500-mb. Low at 35 m. p. h. In this period, the surface to 700-mb. core moved northeastward but the 700-mb. to 500-mb. segment moved, first, east of north and later north of east. In the last 12 hours, the 500-mb. Low moved twice as fast as it did during the first 12 hours.

For the next two days the 500-mb. center slowly revolved counterclockwise becoming orientated southwest of the surface Low position by 1500 GMT on the 30th. In this same 2-day period (28–30th) the surface Low moved 18 m. p. h. for 36 hours then slowed down to 10 m. p. h. in the 12 hours ending 1500 GMT (30th), the 700-mb. Low moved 18 m. p. h. for 24 hours then slowed down to 5 m. p. h. at 1500 GMT (30th) while, for the most part, the 500-mb. center moved at 15 m. p. h.

Concerning the changes on the 28th, two explanations seem plausible. The first was the rapid motion of the 500-mb. Low which moved into the area above the lower section of the core, traveled along with the lower section of the storm for some time, and then appeared to separate from it. The impression is suggested that the lower layers of the core acted as might be expected, but that the core was elongated and then distorted as the 500-mb. center described its seemingly independent course. Examination of various charts, including thickness charts, supported a second factor, that the activity of this period could be attributed to a fresh infusion of cold air which imparted new energy to the storm.

In effect, what took place on the 28th was a reorientation of the core from 700 to 500 mb. In connection with this idea of reorientation, the 300-mb. level was examined in the vicinity of the storm to discover what may have happened. A closed Low on the 0300 GMT chart (27th) between International Falls, Minn. and Fargo, N. Dak. was preceded by a broad tongue of warm air over lower Hudson Bay, as well as to the east of Hudson Bay. This wave of warm air had caused a 24-hour temperature increase of 9° C. at Nichequon, Quebec, Canada, after which the temperatures fell over all Quebec as a broad tongue of cold air swept in behind the wave of rising temperatures. Such a broad lid of cold air above an area of warm air necessarily worked to produce instability and in this way new energy could be made available to the storm.

OTHER ASPECTS OF THE STORM'S MOTION

In spite of various gyrations of the core, the surface Low described a remarkably smooth path across the surface of the earth. Except for the first 15 hours and the last 12 hours of its history the surface Low moved northeastward. Another feature was the uniform rate of motion of 18 to 19 m. p. m. for each 24-hour period during the 4 days until the storm left the North American continent, when it slowed down to about 12 m. p. h. A translation of its rate of movement into percentages of the geostrophic winds at 500 mb. (above the storm) shows that the surface center moved 63 percent the first day, 69 percent the next two days, and 64 percent on the fourth day.

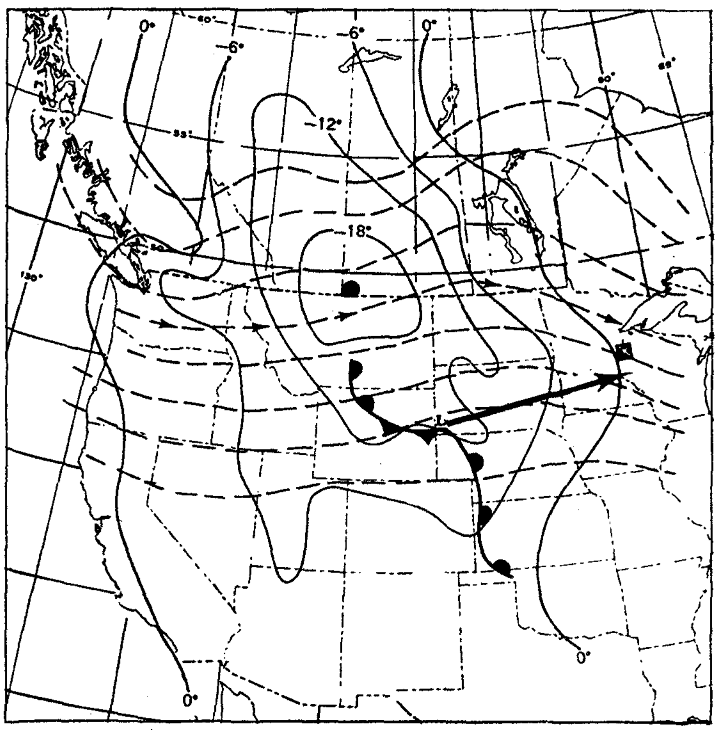

FIGURE 4.—Composite chart, 1830 GMT, September 25, 1951, showing surface fronts at 1830 GMT, 24-hour surface pressure falls (solid line at 6-mb. intervals) ending at 1830 GMT, and 500-mb. flow (broken line) at 1500 GMT. Arrow shows predicted direction (parallel to the 500-mb. flow); dot=center of 24-hour pressure falls; and blocked "X" =surface position of Low 24 hours later.

The motion of the storm may be discussed in a slightly different fashion by comparing the path of the surface pressure changes with the path taken by the low center. The results show that the path of 24-hour pressure changes (falls) coincided with the surface path and provokes the speculation as to whether the direction of these falls could have been accurately forecasted. This will be discussed after the path of the 12-hour falls has been examined.

The path of the 12-hour falls presented somewhat less useful information. These falls on the 25th (1830 GMT) moved east across North Dakota, then southeast across Minnesota, followed by a recurving toward the northeast near La Crosse, Wis., to a location near Wausau, Wis., on the 26th (1830 GMT). So, over the early period of the storm, even a perfect forecast of the movement of the center of 12-hour falls would have yielded poor results, insofar as applying such information to forecasting the path of the surface Low was concerned. From the 26th (1830 GMT) to the 28th (1830 GMT) the fall centers traveled parallel to the surface storm track, but 90 miles to the southeast, from Wisconsin to the westernmost point of Labrador, Canada. After that point, the track of the 12-hour falls departed considerably from the storm track.

FORECASTING THE DIRECTION OF MOVEMENT

The remaining portion of this article will be concerned with a fundamental forecasting problem of foretelling the direction of movement of the surface center. There is considerable literature on this subject, but unfortunately, no one rule or method is successful with all situations. This discussion is limited to the results of a rigid application of one method which might have met with moderate success in this situation. The discussion, of course, is not meant to prove or disprove the method, for this is just one case.

The problem is that of forecasting the position of the surface Low 24 hours later. Since the concern, in this inquiry, is direction and not speed, an assumption is made that the forecast rate of movement is a "perfect" forecast. Forecasting will be based on the 1830 GMT surface map for each day as well as any upper air maps for the time prior to the surface chart. The system to be used involves moving the center of the 24-hour surface pressure falls in the direction of the instantaneous flow of the wind directly above, at 500 mb. In the event that the wind at 500 mb. is too close to a closed center it will be necessary to seek a higher level where the circulation more nearly suggests freedom from cyclonic flow. This is in agreement with usual practice. Furthermore, to make this a rigid application, no allowance will be made for anticipating the future flow pattern of the upper level winds, this to reduce the element of subjectivity and to eliminate the perspective of hindsight.

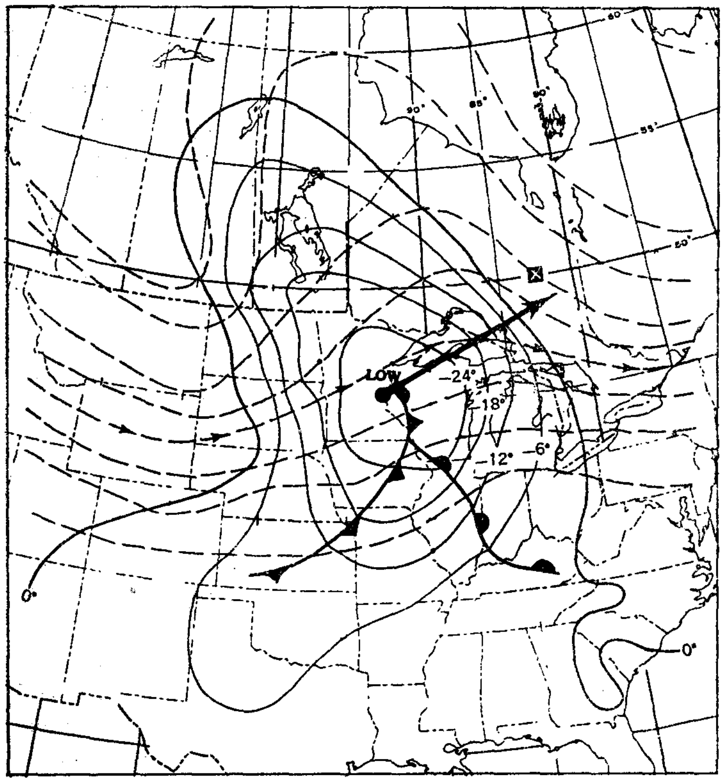

FIGURE 5.—Composite chart, 1830 GMT, September 26, 1951. Arrow is parallel to the 500-mb. flow.

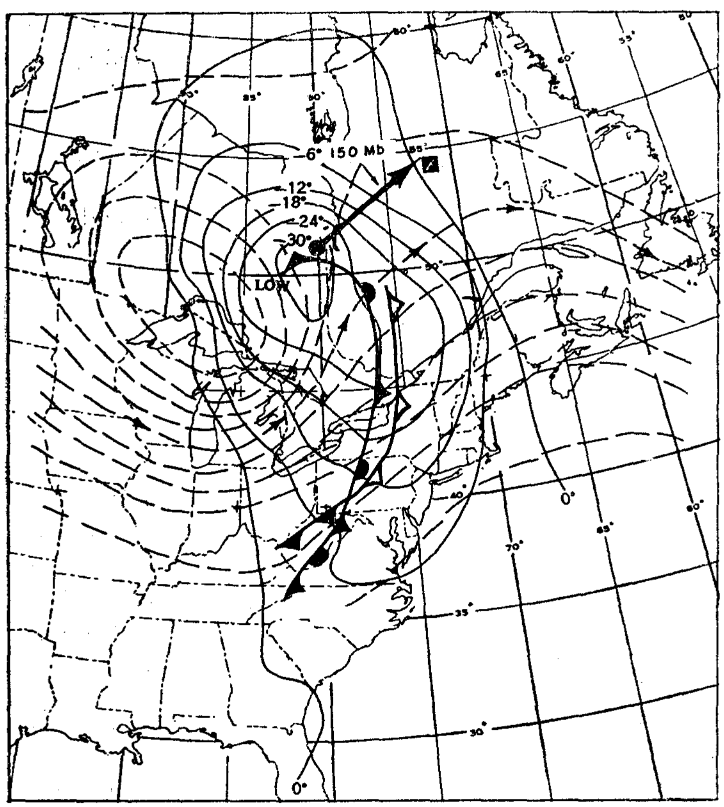

FIGURE 6.—Composite chart, 1830 GMT, September 27, 1951. Arrow is parallel to the 150-mb. flow.

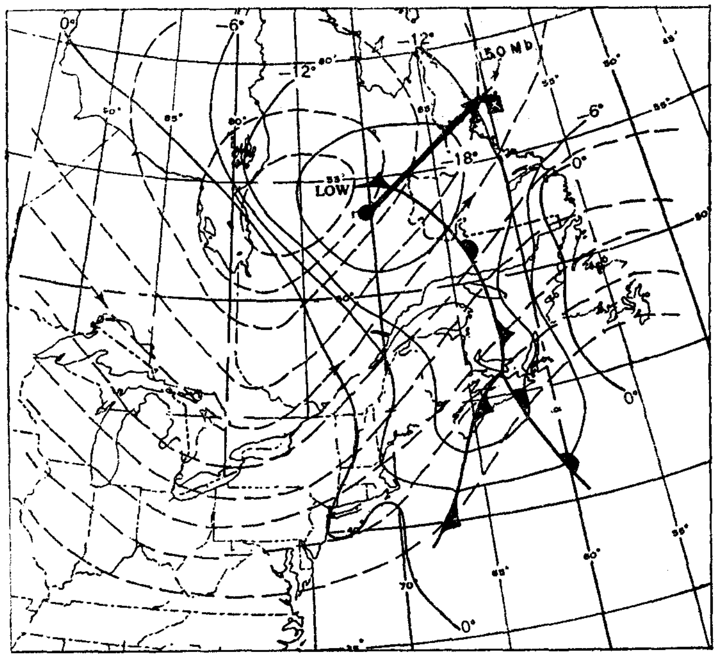

FIGURE 7.—Composite chart, 1830 GMT, September 28, 1951. Arrow is parallel to the 150-mb. flow

On the first day of the series it is evident that two waves are present, one being the subject of this article and the second being over north central Montana (fig. 1). During the next 24 to 30 hours the two centers moved along on just about parallel paths, after which the Montana wave lost its identity. So with this one application of hindsight we shall consider only the southern wave. Figure 4 involves the surface wave, the 500-mb. flow above the wave, and the 24-hour surface katallobars. A line drawn parallel to the 500-mb. flow above the center of falls indicates an easterly movement for the northern wave, which was the path taken by that Low. The solid arrow in figure 4 shows the direction indicated by the flow above the wave and the arrow head points to the position where the center of falls might be expected 24 hours later. The "X" shows the verification position at about 75 miles from the forecasted point. In figure 5, the low center is south of Duluth and the center of 24-hour falls is just southwest of the Low. Drawing a line parallel to the 500-mb. flow and through the center of greatest falls indicates a movement toward the northeast. Assuming a correct forecast of speed, the forecasted path would have brought the surface Low to within 60 miles of the actual position.

Figure 6 presents a case for the use of other levels as it is obvious that use of the 500-mb. flow would require highly subjective interpretation because the center of falls is in an area of divergent flow. Looking to higher levels it was necessary to disregard the 400-, 300-, and 200-mb. levels because the flow at each level was in an area of sharp curvature, requiring the forecasting of the change of flow in the forecast period. The 150-mb. level presented the first level of relatively "uninfluenced" flow and the direction

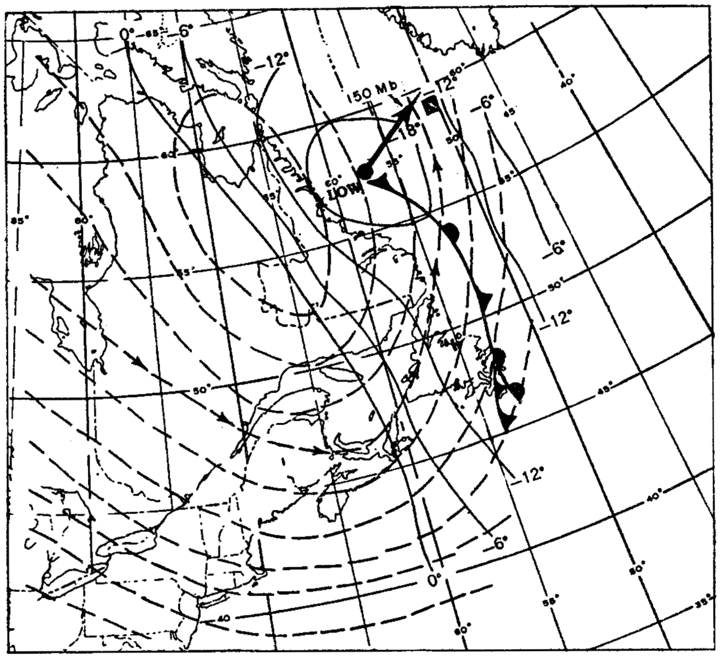

Figure 8.—Composite chart, 1830 GMT, September 29, 1951. Arrow is parallel to the 150-mb. flow.

indicated is in good agreement with the verification direction.

Concerning the above problem it might seem that the forecaster could be dubious of going to the 150-mb. level for a clue, but the following knowledge was available to him. At 1830 GMT of the 27th, a suggestion of the direction could be found by noting that the surface Low had moved to the northeast for 2 days and during the last 24 hours the rate of movement had remained unchanged at the surface. Since no blocking was evident, it seemed, therefore, that persistence would indicate continued movement toward the northeast as well as no change in rate of movement, thus bolstering the forecaster's confidence in the reliability of the 150-mb. indications.

By the 28th (fig. 7) the past history of the storm showed a 3-day northeast track at a steady rate of progression which lends greater weight to the influence of persistence. Although the flow at 500 mb. was once more without sharp curvature at a point above the 24-hour fall center, its use without question hardly seemed likely in view of the previous day's experience. Thus, the forecaster might be expected again to rely upon the 150-mb. flow where the indications were for continued movement in the direction given by persistence.

On the last forecast day (fig. 8), September 29, the following information was available: Persistence of direction and motion for 4 days, and previous success with the 150-mb. flow (direction). A straight application of the 150-mb. flow direction on this day indicated northeast motion. During this last day the rate of movement fell off to 12 m. p. h. and, employing persistence, the low center would have been moved too far by about 150 miles. The question can be raised as to whether the slowing down could have been anticipated. The answer could be a possible yes, if one were to fall back upon the climatological knowledge that Lows often slow down when approaching the coast of Greenland from west to southwest. Perhaps this question cannot be debated from the perspective of a later date, because it is possible that persistence would have weighed too heavily in the thinking of a forecaster on duty at that time.

U. S. GOVERNMENT PRINTING OFFICE: 1951

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